
THE UNITED STATES AIR FORCE TEST PILOT SCHOOL
SCIENTIA EST VIRTUS
"KNOWLEDGE IS POWER"
U.S. AIR FORCE
USAF
USAF TEST PILOT SCHOOL
Flight Test Education, Systems Theory, and Test Safety
The Future of Flight Test Education
Approved for public release; distribution is unlimited.
412TW-PA-19247
Tom "Sulu" Hill
USAF Test Pilot School

Making a Case:

”When It Comes To Future Technology…”

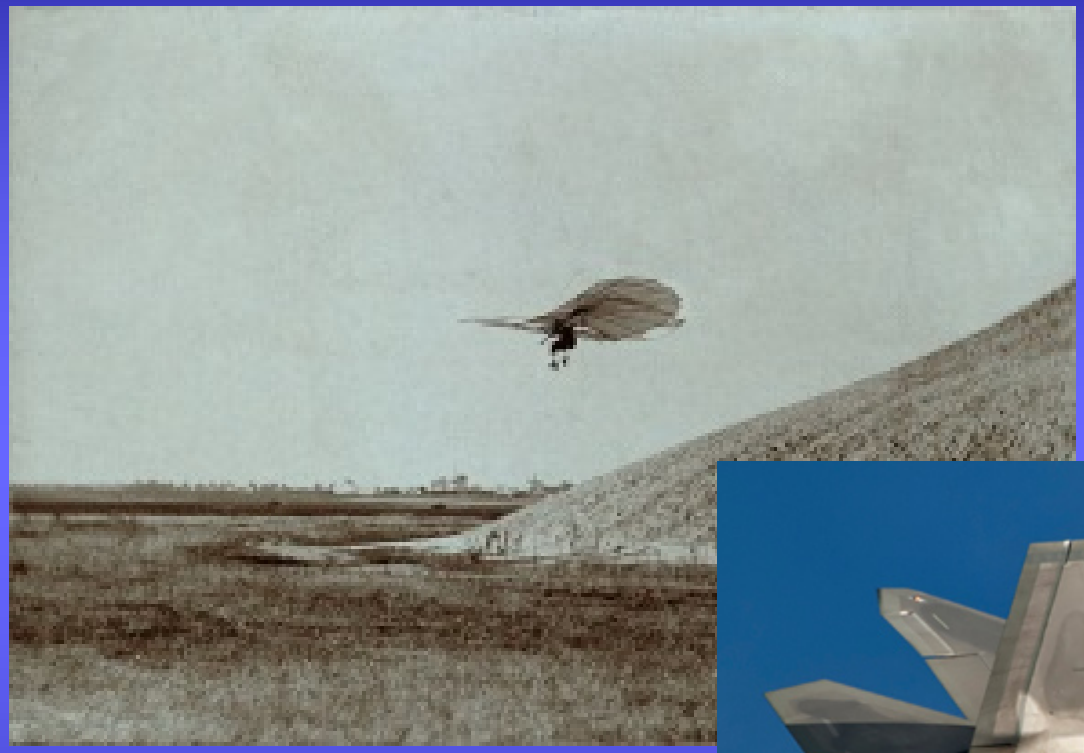
- Legacy Tools To Improve Understanding Are <u>Insufficient</u>

Making a Case:

”When It Comes To Future Technology…”

- Legacy Tools To Improve Understanding Are Insufficient
- New Tools/Perspectives Are Absolutely Necessary

The Forcing Function



Increasing
Complexity

Classic Ways to Deal With Complexity

- **Reductionism:**
- **Statistics:**

Classic Ways to Deal With Complexity

- **Reductionism:**
  - The whole may be explained as the sum of its parts
  - Divide, explain, predict phenomena at more simpler levels
- **Statistics:**

Classic Ways to Deal With Complexity

- **Reductionism:**
  - The whole may be explained as the sum of its parts
  - Divide, explain, predict phenomena at more simpler levels
- **Statistics:**
  - The system is a structureless mass with inputs and outputs
  - Components are sufficiently regular and random in their behavior
  - Law of Large Numbers: quantify the distribution of the output and relate to the inputs

Limitations of Reductionism

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- Natural Sciences:
  - Reductionism…perhaps best suited for natural sciences
  - Still has limitations in chemistry/biology – emergent/macroscopic behaviors
- Psychology/human factors:
  - May have poor external validity (human systems, context matters!)
  - Attribution of unique/biased meanings to data
  - Predictions influencing observations
- Social Sciences:
  - Rich variety of observable phenomena in sociotechnical systems
  - How to define system research question
  - Large quantity / poor control of data
- In general, uncertainties can have disproportionately large impact

"Wicked" region: As complexity increases, the limitations of scientific reductionism become more apparent

Limits of Statistics

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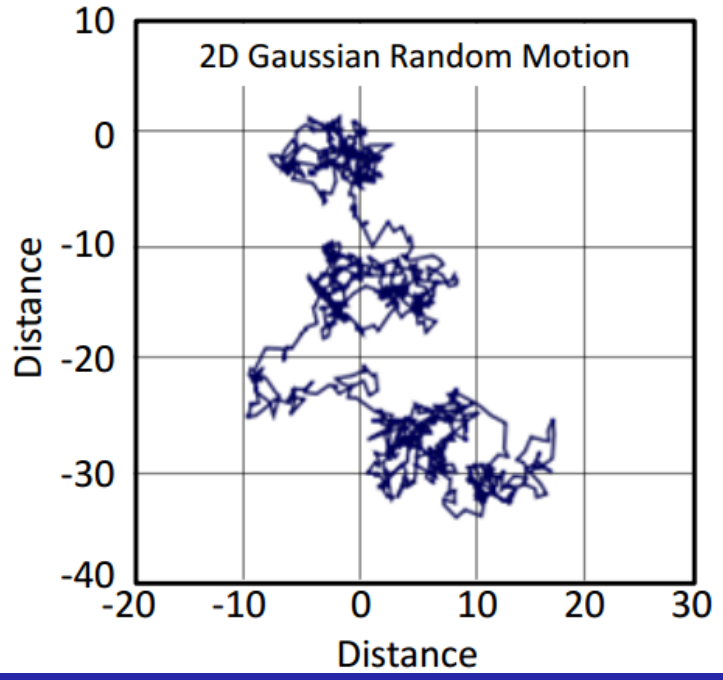
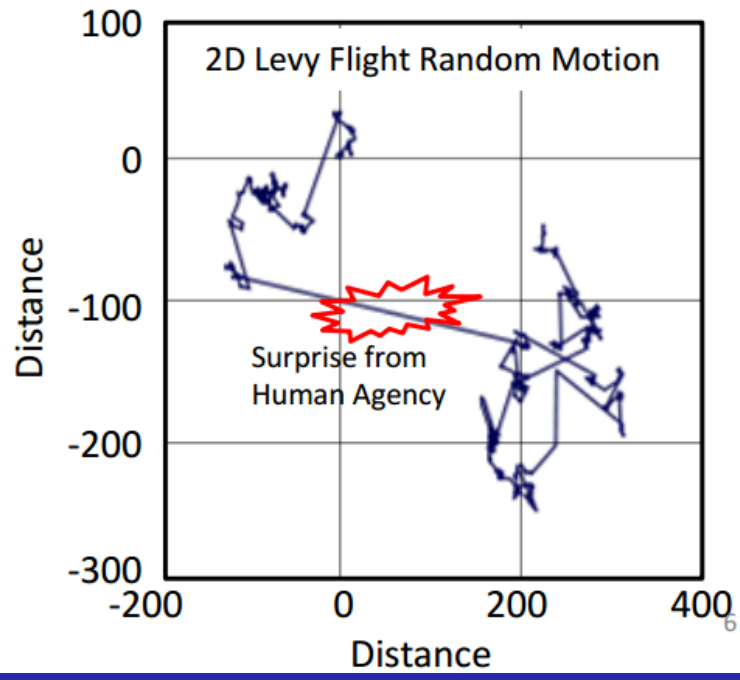
Complicated

- Example: Airplane
- Predictable
- Not as prone to surprise
- Distribution: Gaussian (bell curve)



Complex

- Example: Air traffic
- Can appear predictable
- Susceptible to great surprise
- Distribution: Heavy Tailed



“Black Swan” Distributions

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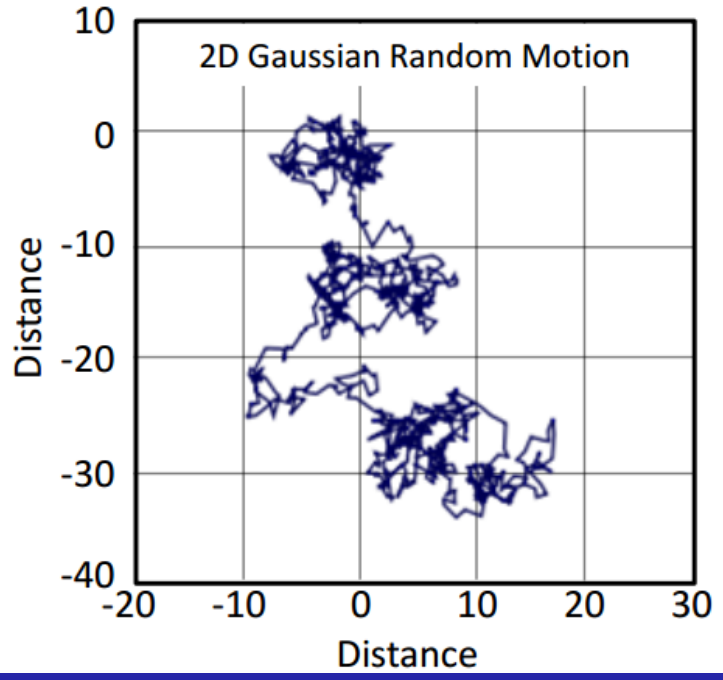

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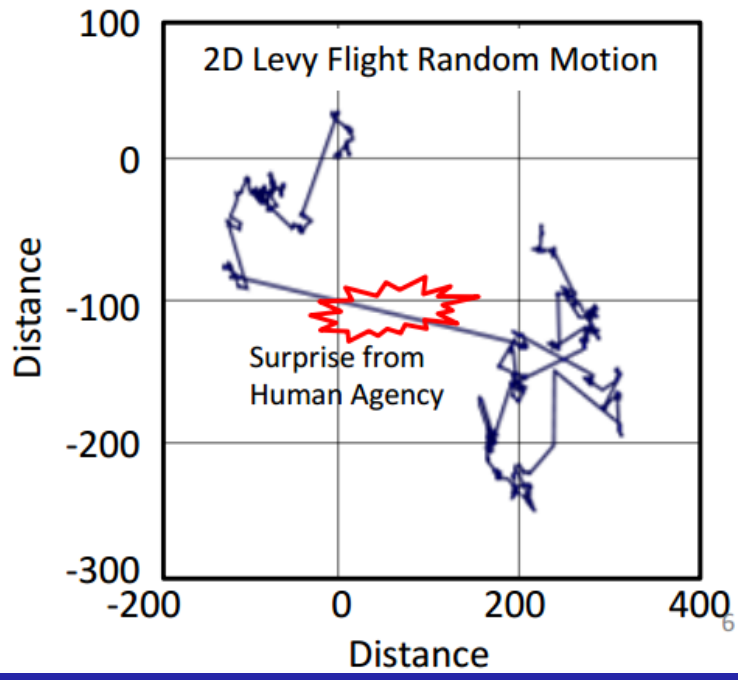
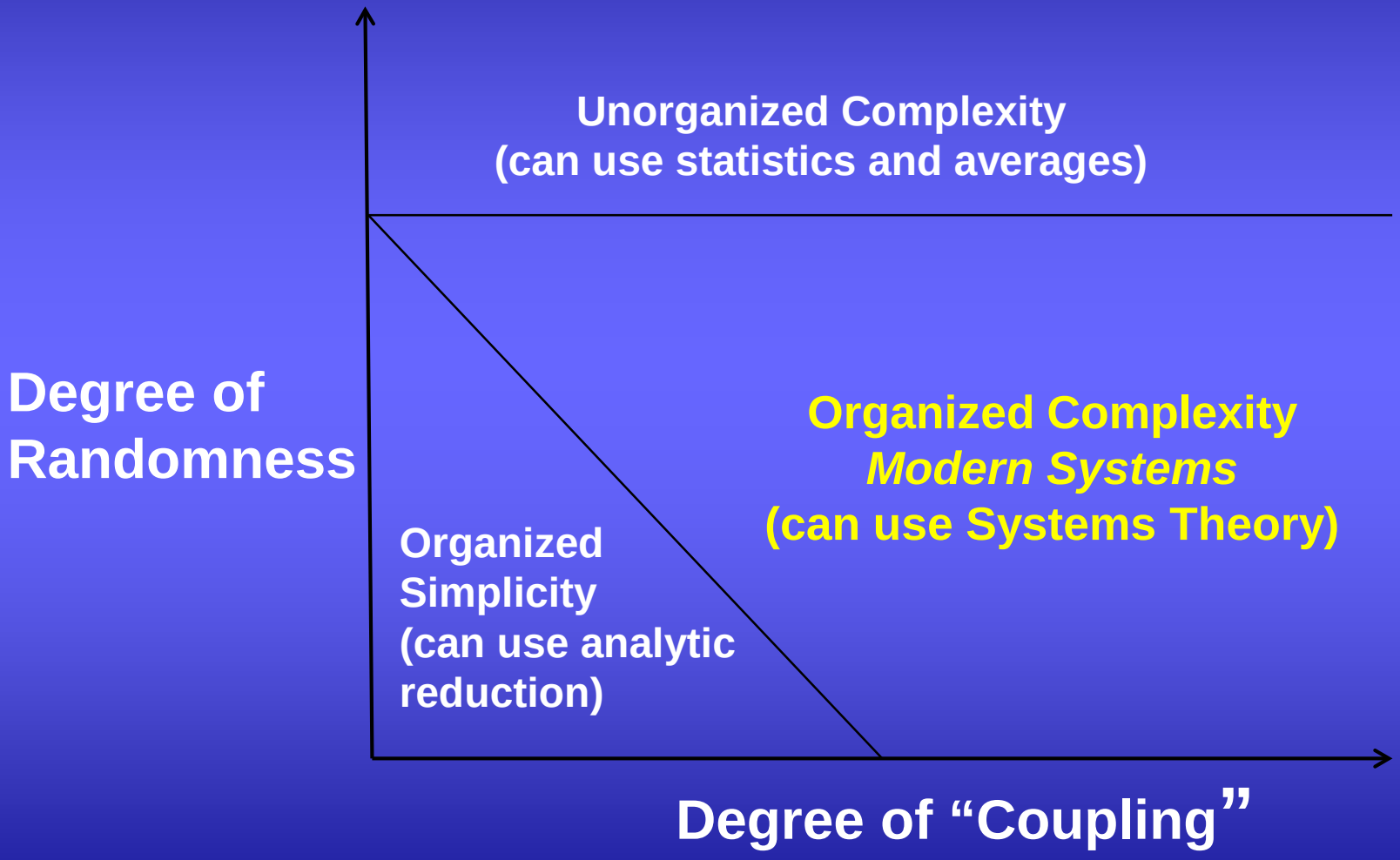


Methodologies (Weinberg, 1975)



Component Failure Vs System Behavior

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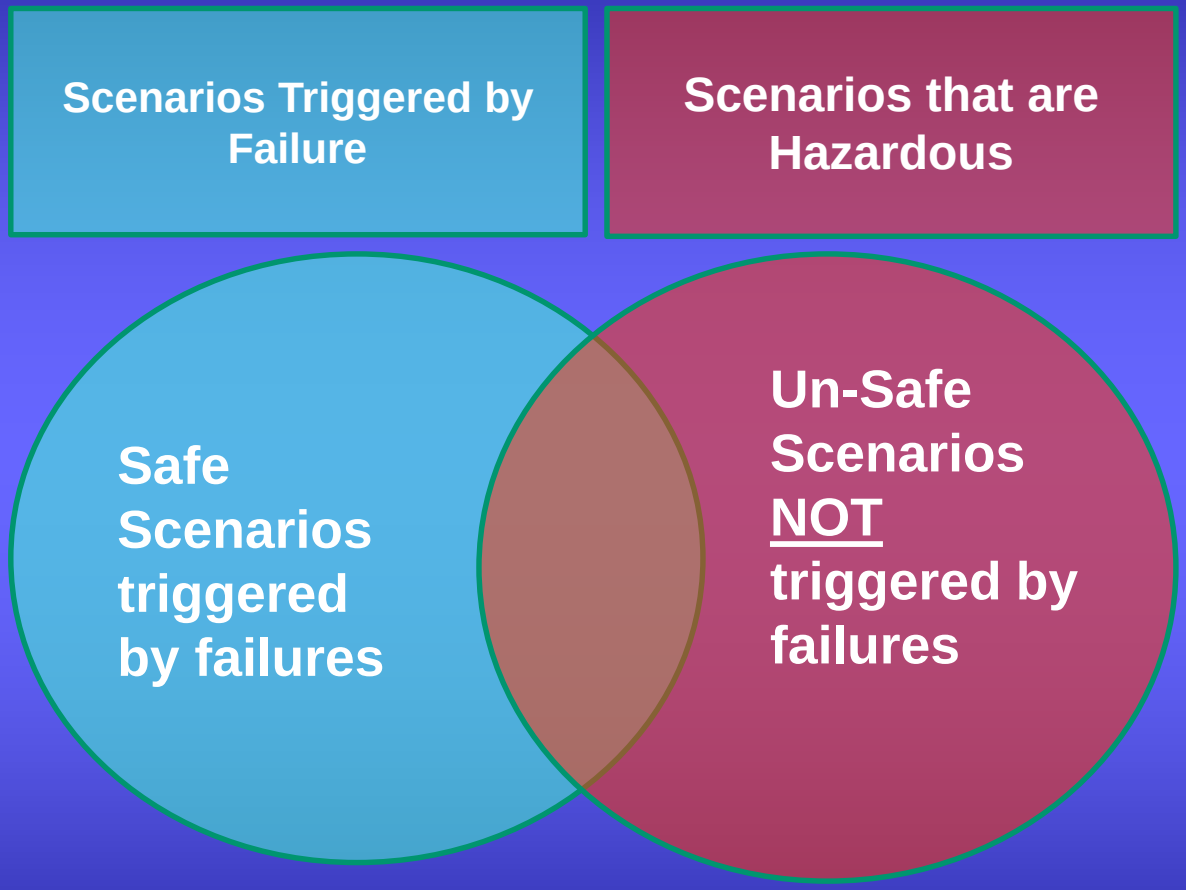

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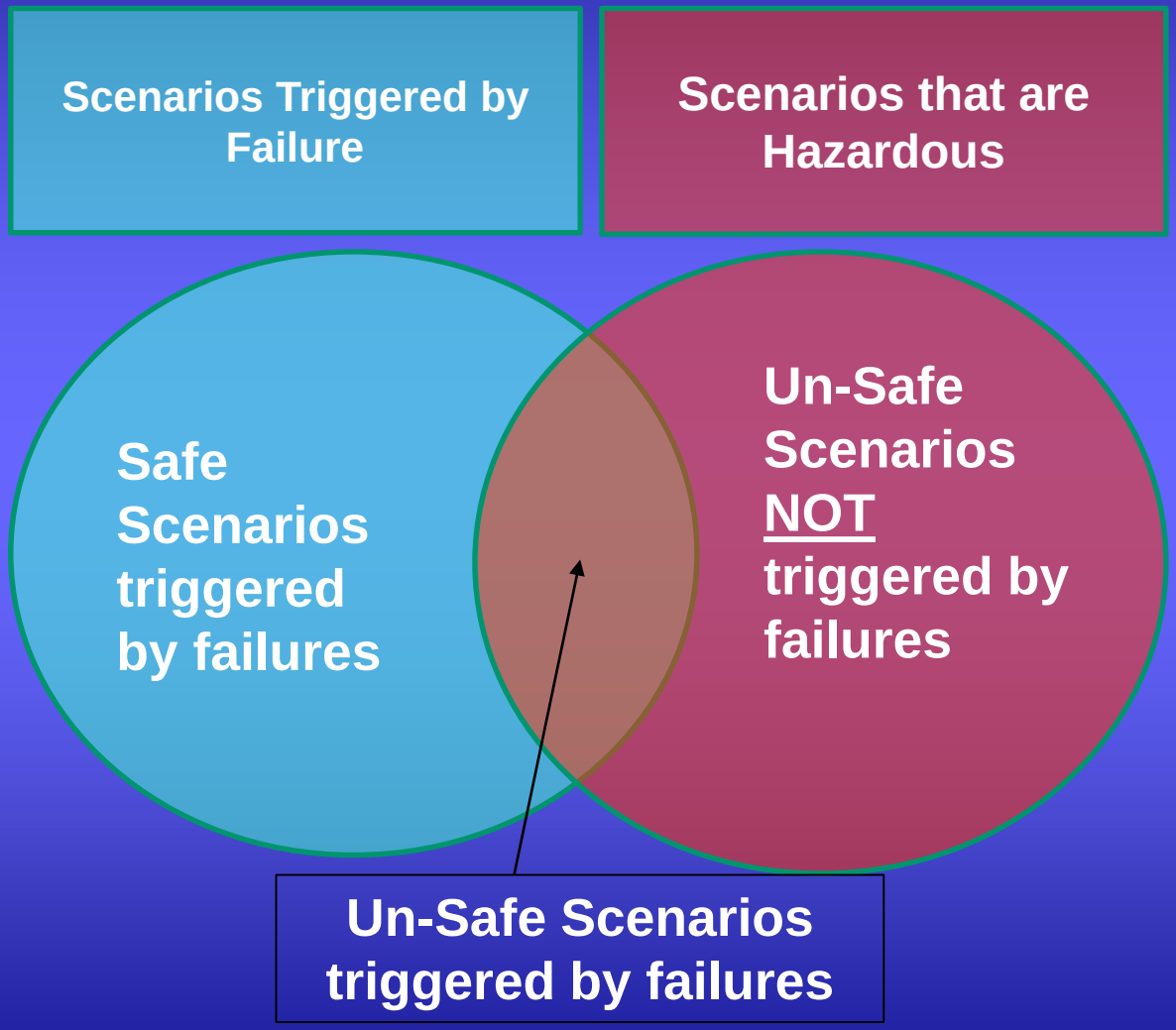
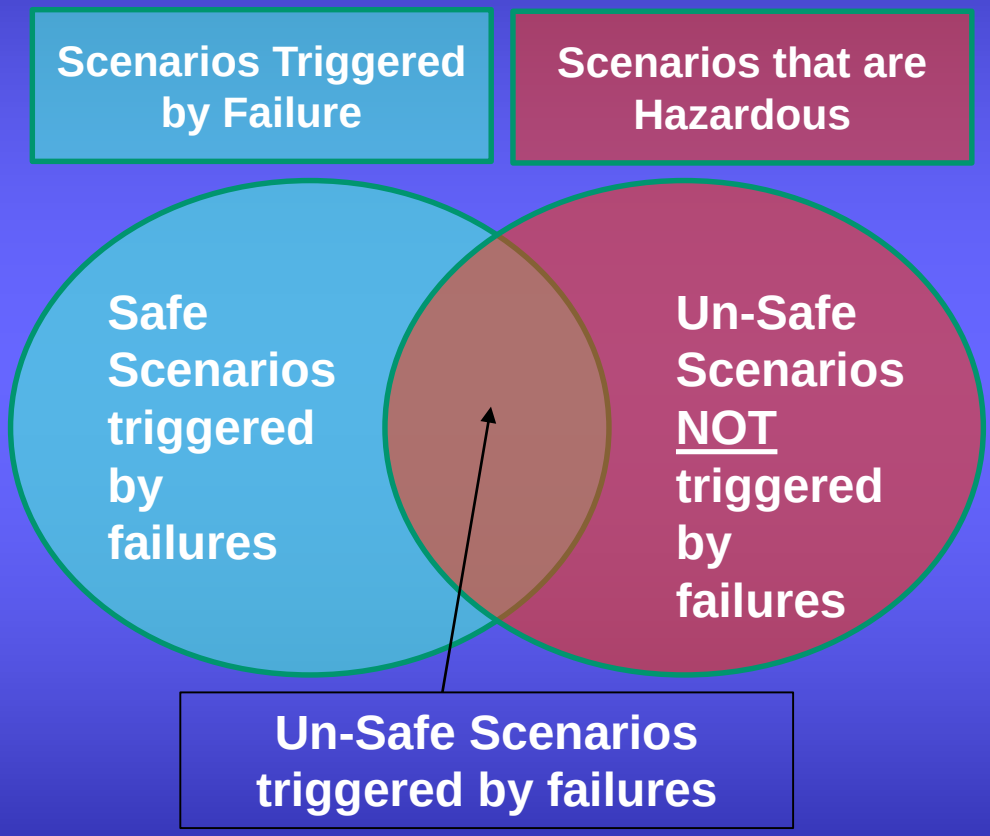


Component Failure Vs System Behavior

- Unsafe Scenarios are unsafe system behaviors
- Can reliability-based analyses be adapted to software and humans?
  - No
    - Software and humans do not ‘fail’ like a physical component



An Example: Internet of Things

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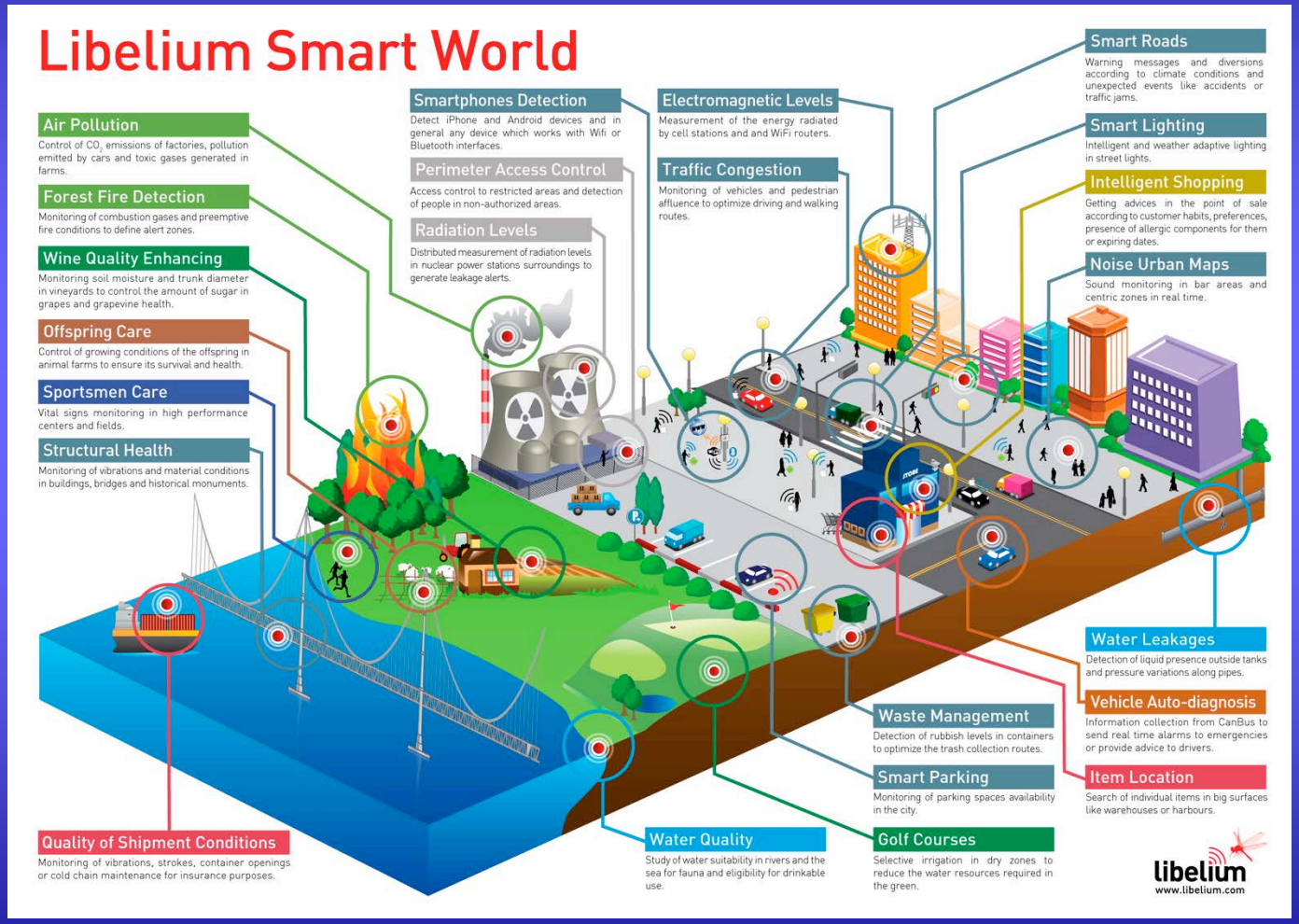

A graphic showing a highly complex ecosystem.

Do Flight Testers Operate In this Environment?

How hard is this to model? Test? Secure?

What's Important? What isn't?

An Example: Internet of Things

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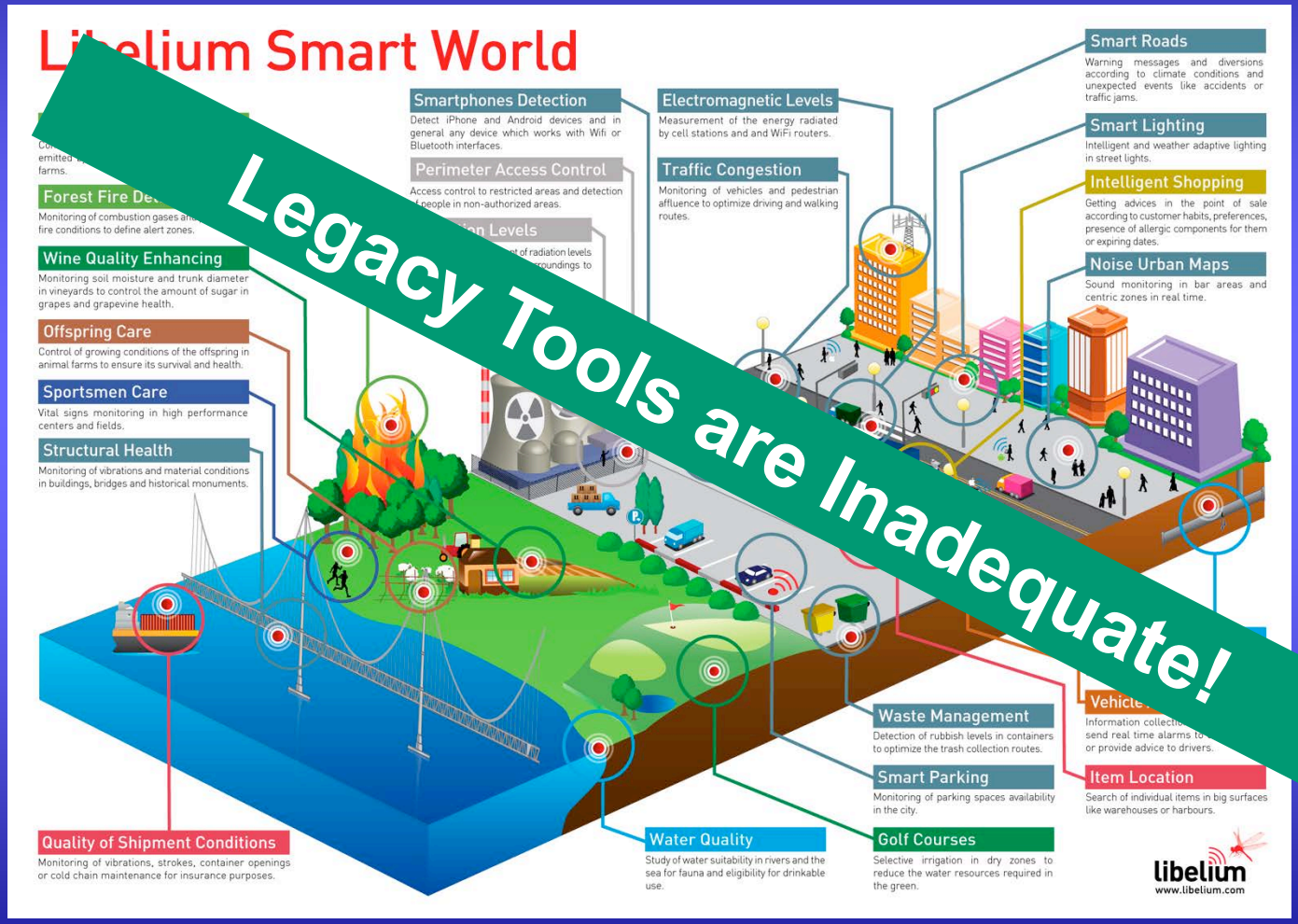

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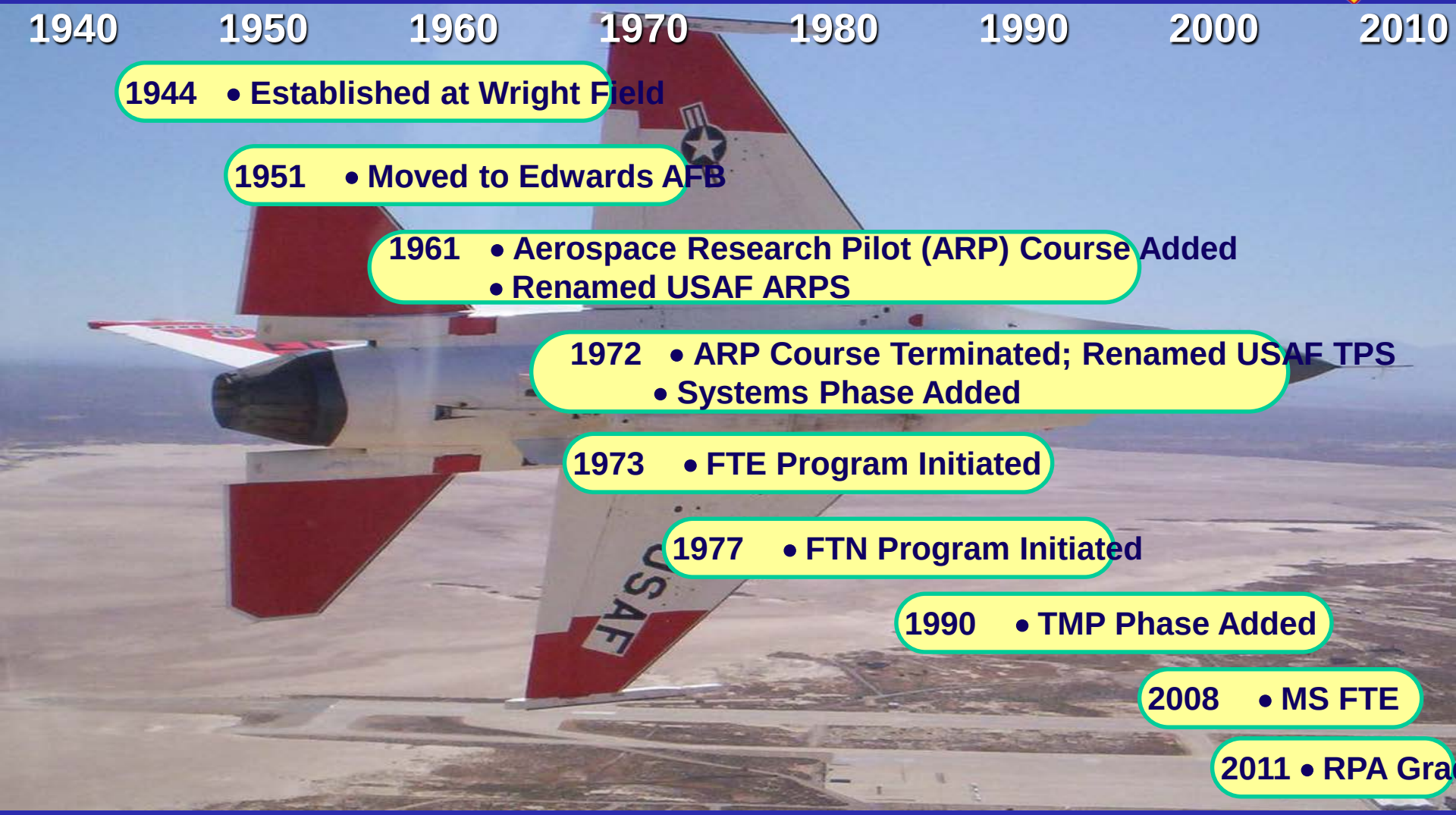
History


1940
1950
1960
1970
1980
1990
2000
2010
1944 • Established at Wright Field
1951 • Moved to Edwards AFB
1961 • Aerospace Research Pilot (ARP) Course Added
• Renamed USAF ARPS
1972 • ARP Course Terminated; Renamed USAF TPS
• Systems Phase Added
1973 • FTE Program Initiated
1977 • FTN Program Initiated
1990 • TMP Phase Added
2008 • MS FTE
2011 • RPA Gra
USAF

TPS Legacy Model: Phase Perspective

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Performance	Flying Qualities	Mission Systems
TM TM TM	Test Management (TMP)	
	Qual Evals	

- Implies a linear progression from one phase to the next; roots in our history → 6 mo + 6 mo
- Inappropriately suggests mutual exclusivity of content

TPS Legacy Model: Phase Perspective

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- Implies a linear progression from one phase to the next; roots in our history → 6 mo + 6 mo
- Inappropriately suggests mutual exclusivity of content
- *Model is not scalable to new challenges*

Re-Think TPS Curriculum

What Are the Core Elements

- Theoretical Knowledge
- Skillset
- Mindset

Re-Think TPS Curriculum

What Are the Core Elements

- **Theoretical Knowledge**
  - ***Technical "Know How"***
  - ***Scientific Understanding***

Re-Think TPS Curriculum

What Are the Core Elements

- **Theoretical Knowledge**
- **Skillset**
  - ***Psychomotor (hands-on)***
  - ***Control Room (operations)***

Re-Think TPS Curriculum

What Are the Core Elements

- **Theoretical Knowledge**
- **Skillset**
- **Mindset**
  - ***Culture (Value)***
  - ***Intrinsic "TPS Secret Sauce"***

Re-Think TPS Curriculum

What Are the Core Elements

- Theoretical Knowledge
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- Mindset
  - Culture (Value, behavior)
  - Intrinsic ”TPS Secret Sauce”

  - *Systems View to Problem Understanding*

Re-Think TPS Curriculum

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What Are the Core Elements

- **Theoretical Knowledge**
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  - ***Culture (Value, behavior)***
  - ***Intrinsic "Secret Sauce"***
  - ***Systems View to Problem Understanding***

Mindset: The Trade Space to Tackle Future Problems

The New Curriculum Model

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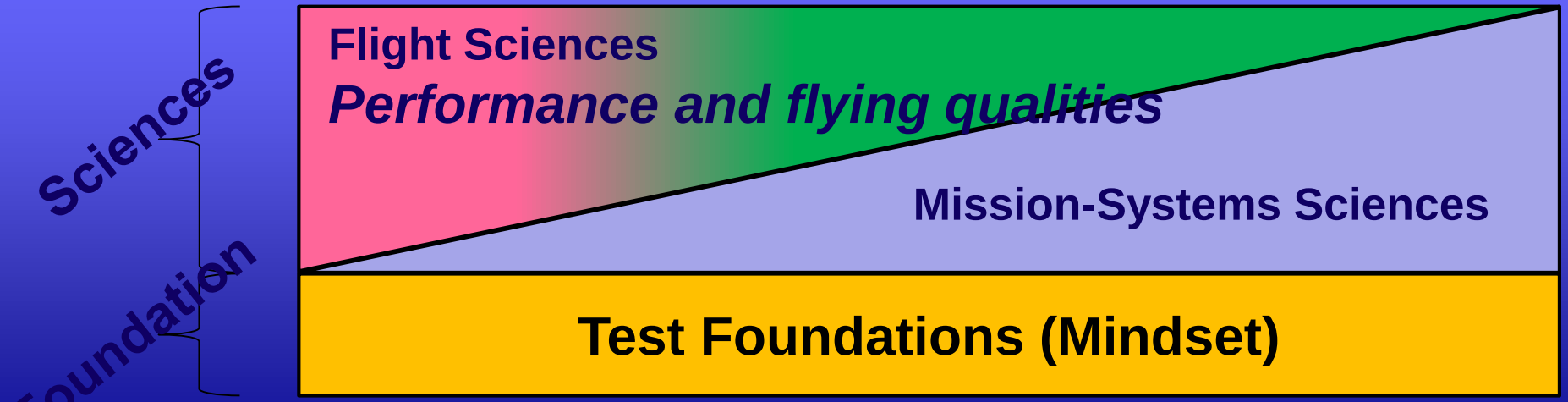
"Phase" approach

EVOLVE

- *Scientific series are scalable in long-term to balance theoretical depth*
- *Formal systems engineering mindset and reinforced test execution skillsets*

"Series" approach



Functional Control Diagram

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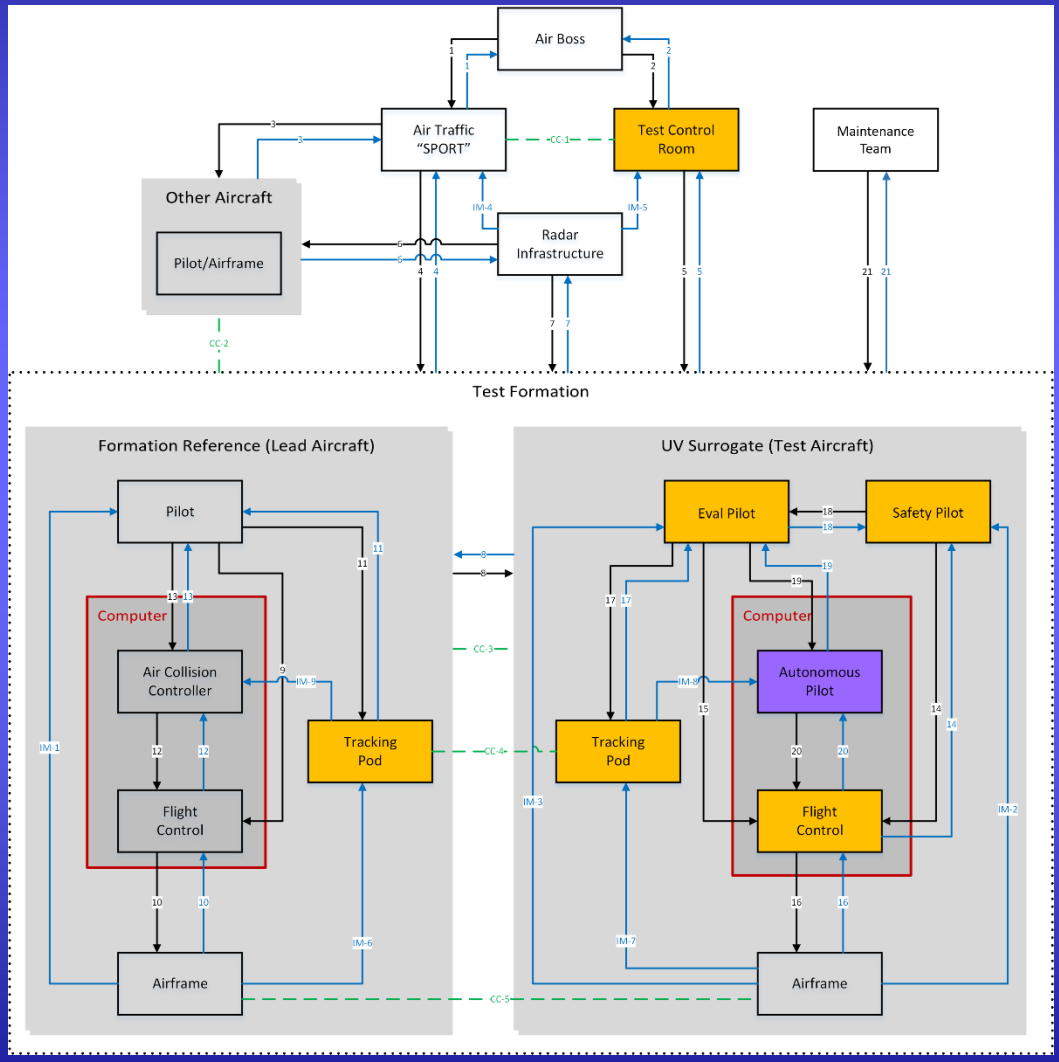
Functional Relationships

Hierarchical

Responsibility
Accountability
Authority



Curriculum & Flight Test Safety?

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Our Philosophy: "Where TPS goes eventually the rest of the community follows"

"Imagine yourself as the trim-tab on the Titanic… eventually the boat is going to turn"

Core Realizations

- **Human-System Interaction Modeling - Yes**

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Core Realizations

- Human-System Interaction Modeling - Yes
- Complexity (e.g . ”Black Swan”) is not smooth
  - Utility of Probabilistic Analysis
- Systems View Creates ”Windows”

Why Change? (Revisited)

- Future Problems are Now – (read the news)
- The cost-benefit of leaning into the complexity space

Questions?

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The United States Air Force (USAF) Test Pilot School (TPS) has undertaken a substantial initiative to prepare its graduates for the challenges of the 21st century. Recent geo-political realities and advances in technologies have motivated USAF TPS curriculum managers to improve their syllabus to better support the advancing needs of the USAF flight test community. An interpretation of survey data concerning challenges faced by USAF flight test teams can be distilled into a single word: complexity. The emergence of intelligent interconnected solutions in social-technical environments has substantially outpaced the efficacy of traditional tools in these situations with a corresponding negative effect on emergent behaviors such as safety. For almost 15 years, the USAF TPS education strategy has been to be as domain agnostic as possible. USAF TPS believes it has had a measure of success with this strategy. The reality is also the advent of technical complexities such as cyber all have characteristics which drive the need for new tools. The assumption is, if USAF TPS does not adapt its curriculum to face increasing complexity and only continues to train legacy techniques and tools, its graduates will not be prepared to deal with the future.

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